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Schedule Variance: A Monetary Value to Determine Time Variancein Construction Project

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Abstract: Earned Value Management (EVM) is a performance measurement method to control projects that allows for the integration of scope, schedule and cost. The objective of this study is to demonstrate that deliberate schedules to guide the implementation of engineering research can be calculated and controlled through EVM techniques. First, the study will explain the main concepts and equationsused to verify the progress of the research andto calculate performance indexes. It will mathematicallydemonstrate that the monetary value obtainedfromcalculating the difference between the Earned Value (EV) and Planned Value (PV) provides a Schedule Variance (SV) that is not easilyevident. In addition, the study will demonstrate that calculating a monetary value using the difference between EV and Actual Cost (AC) provides a more evident metric, referred to as Cost Variance (CV).

Key words: Project management, time variance, schedule variance, cost variance, construction, evident metric

INTRODUCTION

It is quite natural that a value originating from a monetary variance can signify the project Cost Variance (CV). However, it does not necessarily follow that a value resulting from a monetary variance can help in projectingthe project Schedule Variance (SV).

Figure 1 shows that SV is a monetary value resulting from Earned Value (EV) minus Planned Value (PV) and helps to understand the cumulative curve that increases over time of the planned value, actual costs and earned value.

The definition of SV is associated with the difference between two monetary values and represents the project time variance.Regarding this, it is evident that "Another problem with the indicator schedule is that SV is measured in monetary units which makes it difficult to understand" (Creese and Fang, 2010).

Engineering projects, including those centered on buildings, bridges, viaducts, highways, railways, ports and other structuresin the building industry are complex products and center on future delivery (Batselier and Vanhoucke, 2015). They are usually the product of signed contracts between the financier and the contractor who is responsible for the construction. As complex products for future delivery, they are subject to deviations between specifications in the early plan and those in the executed project (De Marco and Narbaev, 2013). The planned value and schedule of a construction project are subject to a wide range of variance, if not properly controlled (Kim and Reinschmidt, 2011).

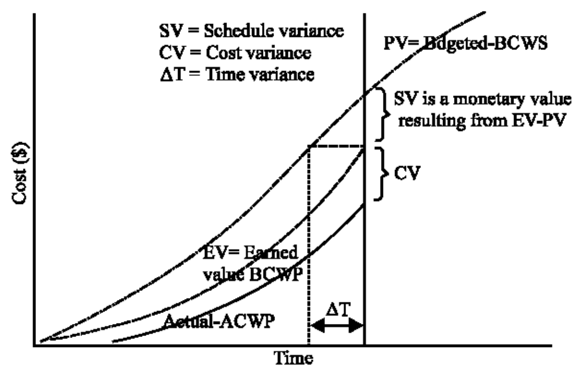

Fig. 1: Relationships between BCWS (PV), BCWP (EV), and ACWP (AC). Adapted from AACE, skills and knowledge of cost engineering

MATERIALS AND METHODS

The problem: The objective of this article is to demonstrate that cost and time inconstruction projects can be calculated and controlled through Earned Value Management (EVM) techniques. Thus, the article will mathematically verify that the analysis of a monetary value resulting from the difference between EV and PV results in SV that is not easily evident. In addition, the monetary value resulting from calculating the difference between EV and Actual Value (AV) provides a more evident metric, referred to as CV.

Earned value fundamentals: To achieve the proposed objective, it is necessary to understand the basics of the

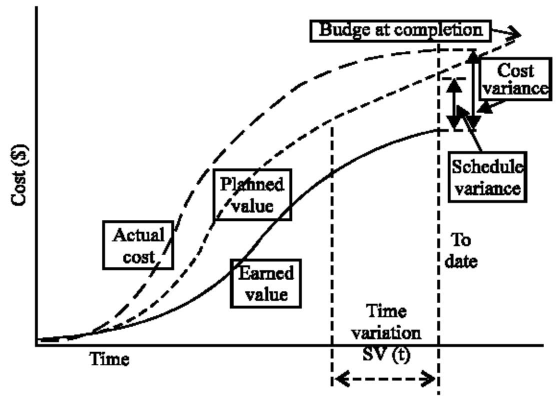

Fig. 2: Components of the Earned Value management (EVM) (Adapted from AACE International)

EVM technique. Therefore, this study will review the main concepts and definitions for each component.

A highly recommended tool for cost and schedule control is EVM of planned research, actual completed research, an estimate of costs at completion and the estimate of costs to complete the research (Vignesh and Sowmya, 2013; Farok and Garcia, 2015; Acebes *et al*., 2015). AACE International, in the Skills and Knowledge of Cost Engineering, refers to earned value as "the periodic, consistent measurement of research performed in terms of the budget planned for that research".

Earned value management "integrates the scope baseline with the cost baseline, along with the schedule baseline to form the performance measurement baseline which helps the project management team assess and measure project performance and progress" (PMI., 2013). It is a technique that compares information between planned and actual research to assess schedule, cost and scope performance as shown in Fig. 2. The EVM technique measures project performance at a given time by comparing information related toactual research done with respect to scope, physical progress and costs.

The Planned Value (PV) arises during the early planning stages of a project. It isrelated to the scheduled activities in the research breakdown structure (De Marco and Narbaev, 2013). The planned value is a budget planned for each control period during the entirety of a project. It represents the physical research performed at specific dates on the construction timeline. The total amount planned for a complete project is the Budget At Completion (BAC). The PV is also entitled Budgeted Cost of Work Scheduled (BCWS) (Wyrozebski and Lysik, 2013).

The Earned Value (EV) comes from the project's progress, expressed in monetary terms at a specific date. With the construction research achieved, it is possible to check EV by applying the percentage effectively executed to the amount Budgeted At Completion (BAC). The cumulative EV provides an accurate measurement of research performed to date which is the Budgeted Cost of Work Performed (BCWP) and represents the planned forecast for the completed research value (Arroyo, 2012). The criteria to calculate the progress for each WBS activityis important to quantify the research in progress.

The Actual Cost (AC) is the accumulated cost incurred for each activity executed at a specific date. It is the expenditure borne to execute the research and EVM usesAC to calculate the project performance. It is also named Actual Cost of Work Performed (ACWP) and represents the real costs to accomplish an activity by a specific date (Wyrozebski and Lysik, 2013).

The Cost Variance (CV) is a measure of timeliness at a particular date in the project. It shows the difference between EV and AC. Then, CV = EV-AC. It represents the measured performance of a project's costs. Ultimately, it is the difference between BAC of the projectand the total accumulated actual cost (AACE, 2004; Steele, 2013). If the consumption of resources is higher than planned, increasing the activity cost, the equation (EV-AC) will reflect thehigher amount spent. In addition, it can verify that the cost performance index (found as CPI = EV÷C) will be less than one.

Schedule Variance (SV) is also a measure of timelines sat a particular date in the project. Then, SV = EV-PV is the difference between EV and PV and SV represents the amount of project advancement or delay with respectto the date planned for delivery. If the elapsed time is greater than planned, SV will show a monetary value representing a greater expenditure of time. In addition, it can also check that the Schedule Performance Index (SPI) which equals EV÷PV, will be less than one. In the end, SV will be equal to zero because all the PVs are appropriately aggregated (Steele, 2013).

With the three components (EV, AC and PV), the project controller can assess the project history in terms of time and cost through EVM. For each evaluation period, the team must calculate variance and performance indexes of cost and schedule, Estimate At Completion (EAC) and Estimate To Completion (ETC) (Bhosekar and Vyas, 2012).

Table 1 illustrates the definitions and concepts of the main components used in the EVM technique. Moreover, it shows the possible range of values that each component can assume and the meaning of value intervals.

Table 1: Definitions and concepts of EVM components

Definition of terms	Concept
Budgeted cost of reseasrch scheduled (PV or BCWS)	BCWS denotes the value of reseasrch to be budgeted
Actual Cost of reseasrch performed (AC or ACWP)	The costs actually incurred in accomplishing the reseasrch performed within a given time period. Use ACWP to denote the total cost spent to complete the task
Budgeted Cost of reseasrch performed (EV or BCWP)	This is identified as earned value. An amount of the reseasrch completed stated as the planned cost or budgeted measure of the reseasrch
Cost Variance (CV)	This is the difference between the planned and actual costs for the accomplished activity It can either be a positive or negative value
Cost Variance percentage (CV%)	This is always expressed as a percentage. A positive value indicates that the project is under budget. A negative value means that the project is over budget
Schedule Variance (SV)	This is the difference between the planned and actual costs for the completed tasks. It can either be a positive or negative value
Schedule Variance percentage (SV%)	This is expressed as a percentage. A positive value indicates that the project is on schedule A negative value means that the project is off schedule
Estimate at Completion (EAC)	This is used to forecast a project budget to obtain a more accurate value of what the project will cost at its completion
Estimate to Complete (ETC)	Estimate how much to spend to complete the project
Determining schedule variances	
SV = BCWP less BCWS	>0 means ahead of schedule <0 means behind schedule
SV% = SV divided by BCWP	
SPI = BCWP divided by BCWS	>1 means more reseasrch performed than scheduled <1 means less reseasrch performed than scheduled
% Complete = 100×SPI	
Determining cost variances	
CV = BCWP less ACWP	>0 means under budget <0 means over budget
CV% = CV divided by BCWP	
CPI = BCWP divided by ACWP	>1 means better progress for the money <1 means less progress for the money
EAC = BAC divided by CPI	
ETC = EAC-AC	

Bhosekar and Vyas (2012)

Table 2: Schedule for construction job of reinforced concrete block

Tasks	Project Budget-Planned Value (PV)	Accomplished (%)	Status to date	Period (days) 1	2	3	4
Shuttering	$800.00	100%	Planned	100%			
			Actual	50%	50%		
Form	$1500.00	100%	Planned		100%		
			Actual		80%	20%	
Steel	$1500.00	60%	Planned			100%	
			Actual			60%	
Concrete	$2400.00	0%	Planned				100%
			Actual				
Total	$6200.00	Planned Value (PV)	Total	$800.00	$1500.00	$1500.00	$2400.00
			Cumulative Total	$800.00	$2300.00	$3800.00	$6200.00

RESULTS AND DISCUSSION

Case example: In order to establish a sound basis for the concepts of the EVM components, Table 2 shows a schedule example of the construction of a block of reinforced concrete. It includes a four-day plan to execute the activities completely. Table 2 shows the activities schedule initially planned and the status of the project by the 3rd day.

The third day is the date to apply the EVM equations to obtain the project status. Table 3 shows information related to the total budget quantity, budget to date quantity, performed to date quantity, budget unit cost, actual unit cost, Planned Value (PV), Actual Cost to date (AC) and Earned Value (EV).

Table 3 indicates that the quantities planned for the steel rebar activity were not accomplished. The planaimed to execute 500 kg by the third day but the actual quantities executed were 300 kg. The unit cost of shuttering was budgeted at \$20.00 m^3 and the steel rebar was budgeted at \$3.00/kg. However, the current unit costs are \$21.00/m^3 and \$3.40/kg, respectively.

Table 3: Quantity, unit cost, reseasrch performed to date (third day) of a concrete block construction

	Quantity			Unit cost		Research to date (third day)			
Activity	Total budget (a)	Budget to date (after 3 days) (b)	Performed to date (after 3 days) (c)	Budget unit cost (d)	Actual to date unit cost (e)	Project Budget at Completion (BAC) (f = a×d)	Planned Value (PV) to 3th day (BCWS) (g = b×d)	Actual Cost to date (AC) (ACWP) (h = c×e)	Earned value (EV) (BSWP) (f = c×d)
Shuttering (m^2)	40.00	40.00	40.00	20.00	21.00	$800.00	800.00	$840.00	$800.00
Formwork (m^2)	60.00	60.00	60.00	25.00	25.00	$1500.00	1500.00	$1500.00	$1500.00
Steel Rebar (kg)	500.00	500.00	300.00	3.00	3.40	$1500.00	1500.00	$1020.00	$900.00
Concrete (m^3)	15.00	0.00	0.00	160.00	160.00	$2400.00	0.00	$0.00	$0.00
Total						$6200.00	$3800.00	$3360.00	$3200.00

Table 4: Cost performance of concrete block construction schedule

Reseasrch to date (position on the third day)										End 4 days	
Earned value analysis								BAC = $6200.00		Estimates scenarios	
	Value analysis (measurement)			Cost variance		Schedule variance		Performance index			
Until the third day	Planned Value (PV) to 3th day (BCWS)	Actual Cost to date (AC) (ACWP)	Earned Value (EV) (BSWP)	Cost Variance (CV)	Cost Variance (CV%)	Schedule Variance (SV)	Schedule variance (SV%)	Schedule Perfor-med Cost perfor-med Index (CPI)	Schedule perfor-med index (SPI)	Estimate at completion (EAC)* Scenario 1: Estimate at current rate	Estimate to complete (ETC)
Activity	PV	AC	EV	EV-AC	CV/EV	EV-PV	SV/PV	EV/AC	EV/PV	BAC/CPI	EAC-AC
Shutte-ring	$800	$840	$800	-$40	-5%	0	0.00%	0.952	1.000	$6510.00	$3150.00
Form	$1500	$1500	$1500	0	0.00%	0	0.00%	1.000	1.000	Scenario 2: Estimate at Budgeted rate	
Steel	$1500	$1020	900	-$120	-13.33%	-600	-40.00%	0.882	0.600	AC+BAC-EV	EAC-AC
Concrete	0	0	0	0		0				$6360.00	$3 000.00
										Scenario 3: Current CPI and SPI	
Total	$3800	$3360	$3200	-$160	-5.00%	-$600	-15.79%	0.952	0.842	AC+(BAC-EV)/CPI/SP EAC-AC	
										$7100.63	$3740.63

Prepared by researchers

Table 4 illustrates the main elements evaluated by the EVM technique. The information obtained from the EVM components makes it possible to calculate the three possibilities for EAC of the concrete block construction under three scenarios:

- Scenario 1-calculate estimate at completion using current CPI rate
- Scenario 2-calculate estimate at completion using budgeted rate
- Scenario 3-calculate estimate at completion using current CPI and SPI rate

Scenario 1 considers the present CPI for EAC at the current rate of CPI. It is assumed that the actual performance of the project will continue in the futureto calculateEAC at the same cumulative CPI of the status to date:

$$EAC = [AC+(BAC-EV)\div CPI] = [AC+BAC\div CPI-EV\div CPI] = [AC+BAC\div CPI-AC] = BAC\div CPI$$

Estimate at completion = (Budget at completion)÷ (Cost performance index). Equation 1 (EAC) research performed at present CPI:

$$EAC = BAC\div CPI \quad (1)$$

Scenario 2 considers the research performed at the budgeted rate for EAC. It considers the actual performance of the project and its actual costs incurred and accumulated until the status to date. Moreover, for future forecast, the planners tipulates that the team will perform the remaining research at the rate originally foreseen in the budget.

Estimate at Completion = (Actual Cost)+(Budget at Completion-Earned Value). Equation 2 (EAC): Research performed at budgeted rate:

$$EAC = AC+(BAC-EV) \quad (2)$$

Scenario 3 considers the research performed at both SPI and CPI rates for EAC. The planner admits for the purpose of forecasting that the team performs the remaining research at the same rate of CPI and SPI at status to date. Estimate at Completion = (Actual Cost)+(Budget at Completion-Earned Value)÷(CPI×SPI). Eq. 3 (EAC): research Performed at Both SPI and CPI:

$$EAC = AC+[(BAC-EV)\div(CPI\times SPI)] \quad (3)$$

In this case, it assumes that the delay in schedule will result in an increased cost for the project. This is the case where delays or anticipations generatean onus or bonus for one party, usually established by an agreement between the owner and contractor. This method is used in cases where the project schedule affectsthe project's finalization (Faro and Garcia, 2015).

In the three scenarios, ETC is determined by ETC = EAC-AC. The ETC is the value remaining necessary to finish the project. ETC affects the Estimate At Completion (EAC) that is the calculation of the final probable cost for the entire project established at current earned value evidence. The three equations previously mentioned can calculate ETC. Each equation presented depends on its acceptability according to several established assumptions at the currently assessed project (Steele, 2013).

Each scenario presented depends on project execution conditions when assessing EVM. In this case where the current date is three quarters of the total time for the project, it is more likely that scenario 3 correctly forecasts the end on the same terms of historical cost and schedule (De Marco and Narbaev, 2013).

Analyzing the project early increases the chances of correcting these distortions, i.e., If the manager controls the physical progress of the project from the beginning, the probability of completing the project on schedule and cost increases. It is important to note that if the consumption of cost elements is higher than planned, it may indicate either an inefficient use of resources or aninaccurate prediction of the needed resources. Thus, the team should make efforts to either correct the performance or correct the early planning to align it with theactual conditions.

At this point, after the main concepts of EVM are presented with a case study containing its equations, the following will demonstrate the proposed problem.

Schedule variance; Mathematical analysis: The case in this article focuses on "Method 1: Units Completed" to measure research progress which is presented in Skills and knowledge of cost engineering. This method is applicable to activities involving repeated production of easily measured pieces of research. The activities listed in Table 4 are easy-to-measure pieces of research. In this case, the current cost is the quantity measuredmultiplied by the unit cost.

The key objective of the EVM analysis (AC, EV and PV) is to determine the variance of costs and schedule for project implementation on a specific date in relation to the planning base line (Colin and Vanhoucke, 2015). Therefore, EVM establishes a comparison between the status of the project and the early planning in terms of cost and schedule. For the case study, the monetary value is the quantity executed (easily measured activity) multiplied by respective activities unit cost, e.g., "the measurement of research performed (i.e., EV) at a certain day was based on the number ofbricks laid that day multiplied by the cost per brick" (Vanhoucke *et al*., 2015).

If the physical progress is aligned with what was planned, then SV = EV, i.e., the budgeted cost of research scheduled (PV) is equal to the budgeted cost of research performed (EV). In this case, the change in the timeline is zero (EV-PV = 0) (Warhoe, 2004). The Schedule Variance (SV) iscalculated as follows: Eq. 4 Schedule Variance (SV):

$$SV = EV-PV \quad (4)$$

Where:

EV = Quantity performed×Budget unit cost
PV = Quantity planned × Budget unit cost
SV = (Quantity performed× Budget unit cost)-(quantity planned×Budget unit cost)

Equation 5 SV according to the quantity variance:

$$SV = (\text{Quantity performed-Quantity planned})\times\text{Budget unit cost} \quad (5)$$

By evaluating the equation shown above, it can be inferred that the determinant factor is the quantity variance(quantity performed quantity planned), i.e., schedule variance. The schedule variance is the amount distributed throughout the project's lifetime. Thus, quantityvariance means schedule variance. The more accurate the progress measurement, the more accurate is the schedule variance. In the example used, EV of steel rebar is given by the quantities of steel used multiplied by the budget unit cost, i.e., 300 kg. This was applied until the third day with a budget unit cost of $3.00/kg. In the steel rebar example, the schedule variance is as follows:

$$SV = EV-PV$$

Where:

EV = Quantity performed×Budget unit cost = 300kg×$3.00/kg
PV = Quantity planned×Budget unit cost = 500kg×$3.00/kg

Therefore:

$$SV = (\text{Quantity performed} \times \text{Budget unit cost}) - (\text{Quantity planned} \times \text{Budget unit cost})$$

where, $SV = (300kg \times \$3.00/kg)-(500kg \times \$3.00/kg)$

$$SV = (\text{Quantity performed-quantity planned}) \times \text{Budget unit cost}$$

Where:

$SV = (300kg-500kg) \times \$3.00/kg$

$SV = -\$600.00$

A result <0 means that the activity is performed later than planned. The determinant factor in this case is the quantity variance (300-500 kg). Therefore, it becomes evident that the equation to determine SV is the0 quantity variance multiplied by the same budgeted unit cost. Applying the same budgeted unit cost to each part that composes the equation is the fundamental logical concept used to determine SV, leading to the conclusion that SV is a monetary value given for the quantity variance multiplied by budgeted unit value.

Cost variance; mathematical analysis: On the other hand, the Cost Variance (CV) is calculated as follows: Equation 6: Cost Variance (CV):

$$CV = EV-AC \tag{6}$$

Where:

EV = Quantity performed×Budget unit cost

AC = Quantity performed×Actual unit cost

Therefore:

$$CV = (\text{Quantity performed} \times \text{Budget unit cost}) - (\text{Quantity performed} \times \text{Actual unit cost})$$

Equation 7: CV according to unit cost variance:

$$CV = (\text{Quantity performed}) \times (\text{Budget unit cost-Actual unit cost}) \tag{7}$$

By evaluating the equation shown above, it can be inferred that the determinant factor is the change in the cost unit variance (budget unit cost-actual unit cost), i.e., cost variance. In the example used, AC of steel rebar is given by the amount of steel used multiplied by the actual unit cost, i.e., 300 kg. This was applied until the third day with an actual unit cost of $3.40/kg. In the steel rebar example, the Cost Variance (CV) is calculated as follows:

$$CV = \text{Cost Variance}$$

$$CV = EV-AC$$

Where:

EV = Quantity performed×Budget unit cost = 300 kg×$3.00/kg

AC = Quantity performed×Actual unit cost = 300 kg×$3.40/kg

Hence:

- $CV = (\text{Quantity performed} \times \text{Budget unit cost}) - (\text{Quantity performed} \times \text{Actual unit cost})$
- $CV = (300\ kg \times \$3.00/kg)-(300\ kg \times \$3.40/kg)$
- $CV = (\text{Quantity performed}) \times (\text{Budget unit cost-Actual unit cost})$
- $CV = (300kg) \times (\$3.00/kg-\$3.40/kg)$
- $CV = -\$120.00$

A result <zero means that the activity is performed at a higher cost thanbudgeted. The determinant factor in this case is the unit cost variance ($3.00/kg-$3.40/kg). Itthen becomes evident that the equation to determine CV is the variance of the unit cost multiplied by the same quantity performed. Applying the same quantity performed on each part that composes the equation is the fundamental logical concept used to determine CV. This leads to the conclusion that CV is a monetary value given for the unit cost variance multiplied by quantity executed to date.

In addition to the EVM technique, planners and controllers used the earned schedule theory more frequently. The introduction of the Earned Schedule (ES) concept gained acceptance among managers because it improves performance evaluation and forecasting of project duration. It provides an alternative to equations, whose components relate to the project development time (Lipke, 2014; Warburton, 2014).

Figure 3 illustrates the elements used to calculate SV and SPI related to time.The concept of ES offers the opportunity to foreseethe project completion date and is the connection to increasing schedule analysis from the EVM data (Narbaev and De Marco, 2014).

Lipke (2014) explains the concept of ES whose results focus on the elapsed time of the project. Thus, the contents of the equations used encompass data about the duration of the project until the date of assessment, i.e., the information used in the equations is derived from periods available on the abscissa axis instead of the monetary values information from the ordinate axis.

Lipke (2014) wrote that there is no doubt about the utility provided by the concept of schedule variance

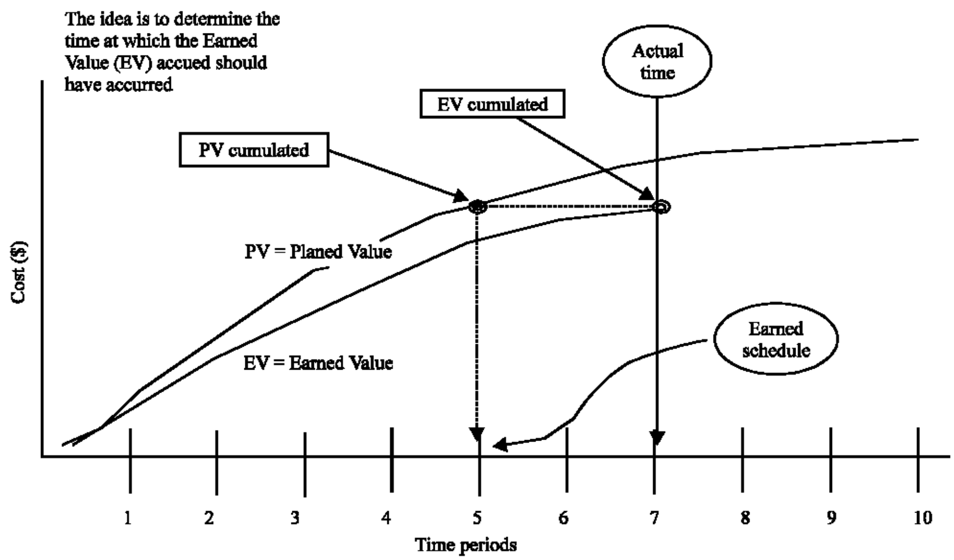

Fig. 3: Earned schedule concept adapted from Lipke (2014)

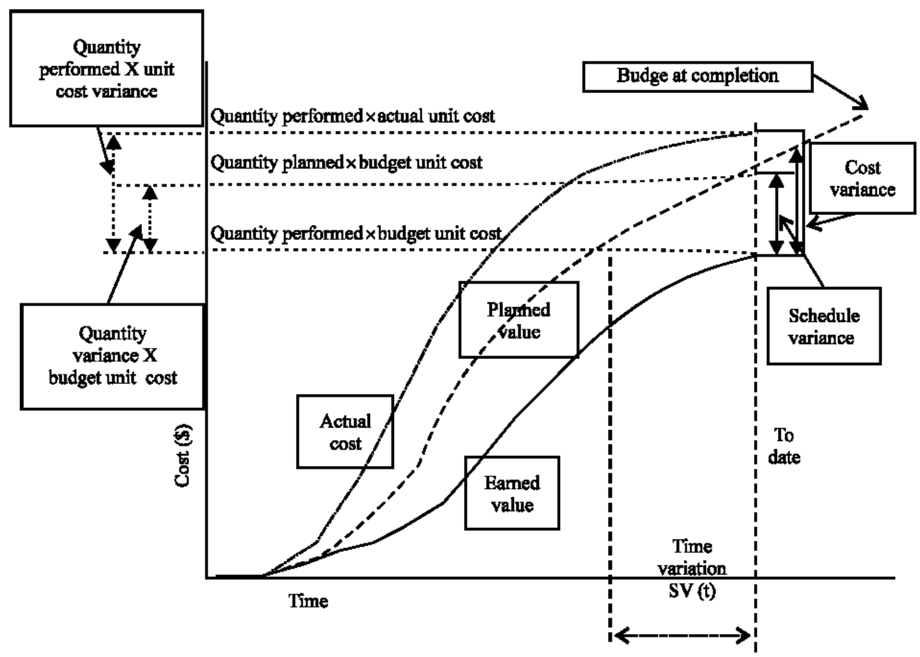

Fig. 4: Unit cost variance and quantity variance. Prepared by researchers

(time) and schedule performance index (time), abbreviated as SV (t) and SPI (t), respectively. “The idea is to determine the time at which the earned value (EV) accrued should have occurred” (Lipke, 2014). The following equations compute the values. Eq. 8: Schedule Variance (time): SV (t):

$$SV(t) = ES\text{-}AT \tag{8}$$

Eq. 9: Schedule performance index (time): SPI (t)

$$SPI(t) = ES/AT \tag{9}$$

where, AT is the actual time, i.e., the duration from the start of the project to the time at which EV is measured (Lipke, 2014).

Equation 5, expressed by SV = (Quantity performed-quantity planned)×Planned unit cost, represents the result of the article object as shown in Fig. 4 which is evidence that:

- Quantity Variance (QV) = Quantity performed-quantity planned
- Unit Cost Variance (UCV) = Budget unit cost- actual unit cost
- 000 SV = (Quantity performed-quantity planned)×Planned unit cost

Regardless of the type of existing contract between the owner and contractor or whether the owner is the constructor, the planner calculates the quantities, productivity, total and unit cost for each activity to establish targets to use in meticulous control.

The report of each project evaluation period must show the behavior of QV and UCV and identify the rate of increase or decrease in its performance throughout the periods. It can show the influence of QV and UCV with respect to good and bad performance in costs and time to date. Further, it can detect the influence in a possible time recovery plan of the activity or project. The equations presented in Fig. 4 show that there is a close relationship between QV and the SV(t) of activity execution.

The Earned Quantity (EQ) is the quantity actually performed at the Earned Schedule (ES) point shown in Fig. 3. This approach provides an opportunity to control the index performance and variances by the stochastic techniqueas is done for EV, PV, CPI, SPI (Colin and Vanhoucke, 2015; Grau and Back, 2015; Hwang 2015). It can verify if the QV and UCV are under expectations.

Final considerations: It might seem strange to determine the schedule variance by an equation that uses monetary values, as with EMV (SV = EV-PV). However, after a detailed analysis of the parts of the equation, it is evident that such an idea is correct. The variable elements in the equation are the early planned quantities and the actual quantities executed to date.

There is the option of using the alternative equations to calculate SV(t) and SPI(t) as proposed by Lipke (2014). However, thisstudy achieves its purpose by demonstrating that even using monetary values from the abscissa axis resultsin a schedule variance.

The equation ensures that the determinant factor for calculating SV is given by Quantity performed-Quantity planned to date. Thus, SV = quantity variance×planned unit cost.

As shown in Fig. 4, the project team can control each activity, a group of activities or all project activities. The quantities can represent measurement of progress in research hours, volume, area, linear extents, percentage of amount completed and others. The control team can report the quantity variance and changes in the timeline to provide the correct understanding of the relationship between the quantity deviations and delayed or advanced time.

The graph shown in Fig. 4 allows the project controllers to check the historical variance between planned and executed quantities for each controlled period and check the accumulated variance rate or the one for the period. The control allows for areporting of the rate of a recovery plan for quantities, unit cost and time for a critical activity and the expected total time for completing a project.

REFERENCES

Acebes, F., M. Pereda, D. Poza, J. Pajares and J.M. Galan, 2015. Stochastic earned value analysis using Monte Carlo simulation and statistical learning techniques. Intl. J. Project Manage., 33: 1597-1609.

Arroyo, L.M.A., 2012. Pragmatic earned value model to effectively plan and control construction projects. AACE. Intl. Trans., 1: 1049.01-1049.37.

Batselier, J. and M. Vanhoucke, 2015. Construction and evaluation framework for a real-life project database. Intl. J. Project Manage., 33: 697-710.

Bhosekar, S.K. and G. Vyas, 2012. Cost controlling using earned value analysis in construction industries. Intl. J. Eng. Innovative Technol., 1: 324-332.

Colin, J. and M. Vanhoucke, 2015. A comparison of the performance of various project control methods using earned value management systems. Expert Syst. Appl., 42: 3159-3175.

Creese, R.C. and Y. Fang, 2010. Time-based schedule performance index. Cost Eng. J., 52: 18-20.

De Marco, A. and T. Narbaev, 2013. Earned value-based performance monitoring of facility construction projects. J. Facil. Manage., 11: 69-80.

Farok, G.M.G. and J.A. Garcia, 2015. Developing group leadership and communication skills for monitoring EVM in project management. J. Mech. Eng., 45: 53-60.

Lipke, W., 2014. Introduction to earned schedule. Project Manage. World J., 3: 1-11.

Narbaev, T. and A. De Marco, 2014. An earned schedule-based regression model to improve cost estimate at completion. Intl. J. Project Manage., 32: 1007-1018.

PMI., 2013. A Guide to the Project Management Body of Knowledge (PMBOK GUIDE). 5th Edn., Project Management Institute, Pennsylvania, USA., ISBN:9781935589679, Pages: 589.

Steele, M.D., 2013. An earned value analysis framework for evaluating project portfolios. AACE Intl. Trans., 1: 1333.1-1333.12.

Vanhoucke, M., P. Andrade, F. Salvaterra and J. Batselier, 2015. Introduction to earned duration. Measurable News, 1: 15-27.

Vignesh, N. and S. Sowmya, 2013. Analysis of estimate at completion of a project's duration to improve earned value management system. Intl. J. Eng. Res. Technol., 2: 1056-1061.

Warburton, R.D.H., 2014. A new schedule estimation technique for construction projects. Organiz. Technol. Manage. Constr. Intl. J., 6: 1075-1082.

Warhoe, S.P., 2004. The basics of earned value management. AACE Intl. Trans., 1: CS71-CS80.

Wyrozebski, P. and K. Lysik, 2013. Time and cost controlling with earned value technique-yellow pages directory case study. J. Manage. Financial Sci., 6: 51-69.